CHAPTER 9: SHIPMENTS ANALYSIS

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CHAPTER 9: SHIPMENTS ANALYSIS

9.1 INTRODUCTION

The shipments model provides an estimate of the rate at which an in-service stock of existing transformers may be replaced by new, more-efficient transformers meeting the trial standard. The core of the shipments analysis is an accounting model that the Department developed to simulate how existing and future purchases are incorporated into an in-service stock of aging transformers that are gradually replaced. An estimate of the rate at which transformers are purchased and replaced is a key input to the Department's estimate of the national impacts of trial standards for distribution transformers.

In addition to using estimates of distribution transformer shipments as an input for the national energy savings (NES) analysis (see Chapter 10 of this Technical Support Document) for the Notice of Proposed Rulemaking (NOPR), the Department will use the shipments estimates as input to the manufacturer impact analysis (MIA). That analysis estimates the impact of potential efficiency standards on businesses (see Chapter 12).

9.2 MODEL OVERVIEW

The Department uses forecasts of shipments for a base case and a standards case to provide an estimate of the annual sales and in-service stock of transformers for the forecast period. The estimate includes the age distribution of transformers for each transformer type (classified according to product classes) and each transformer size. The model uses the annual transformer sales and the age distribution of the in-service stock to calculate equipment costs for the net present value (NPV) and energy use for the NES, respectively. The Department chose an accounting model method to prepare shipment scenarios for the base case and several trial standard cases. The model keeps track of the age and replacement of transformer capacity given a projection of future transformer sales growth.

Figure 9.2.1 presents a graphical flow diagram of the shipments model portion of the distribution transformer national impact (NES and NPV) model and spreadsheet. In the diagram, the arrows show the interconnectivity of data exchanges between calculations. Inputs are shown as parallelograms. As data flows from these inputs, it may be integrated into intermediate results (shown as rectangles) or through integrating sums or differences (shown as circles) into major outputs that are shown as boxes having curved bottom edges.

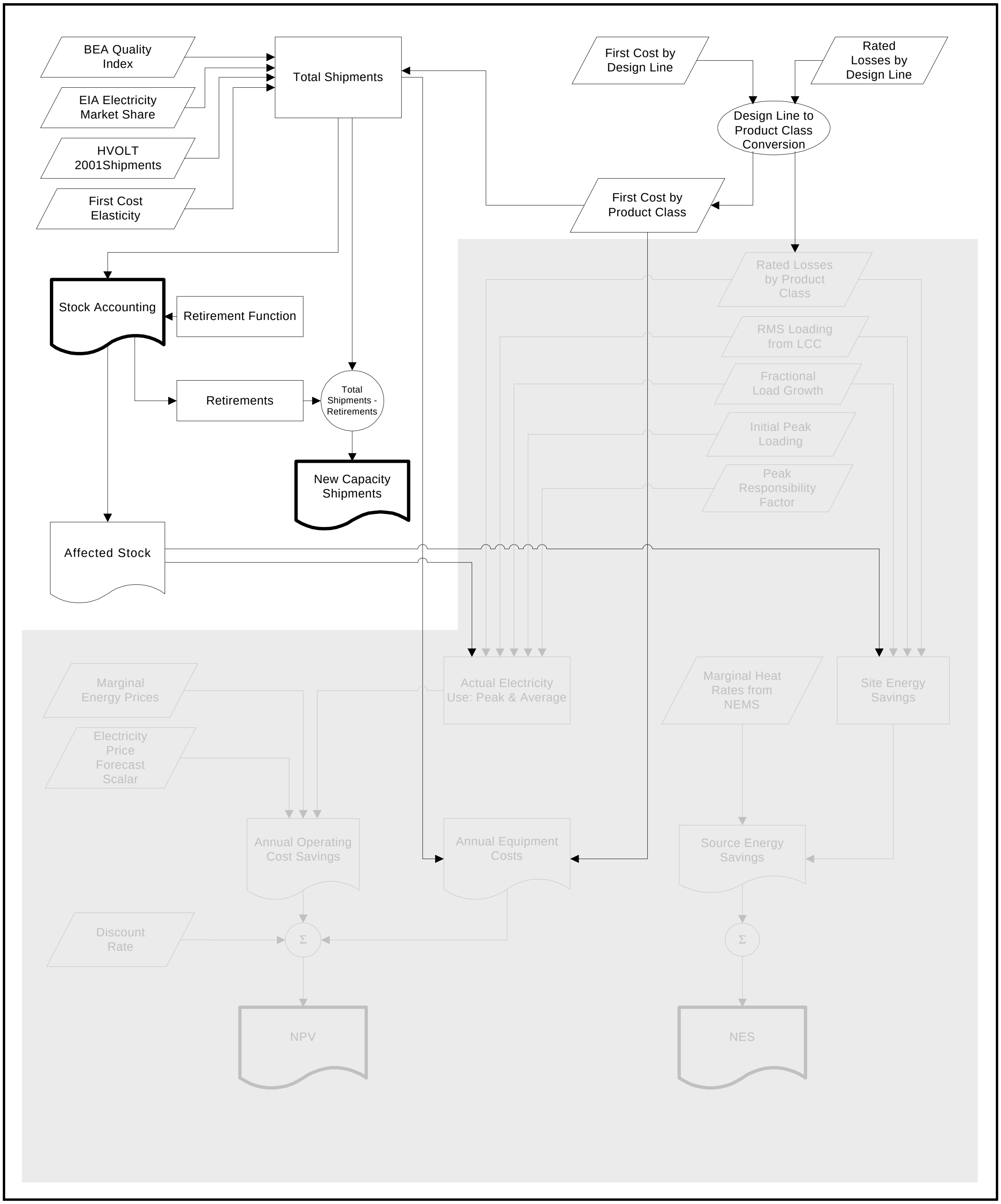

Figure 9.2.1 Shipments Model Flowchart

As illustrated in the flow diagram, the Department organized shipments into two categories: replacements and new capacity. Replacements occur when transformers break down, corrode, are struck by lightning, or otherwise need to be replaced. New capacity purchases occur due to increases in electricity use that may be driven by increasing population, commercial and industrial activity, or growth in electricity distribution systems. The model starts with an estimate of the overall growth in transformer capacity and then estimates shipments for particular design lines using estimates of the relative market share for different design and size categories. The steps for the shipments calculation are:

1. Collection of available data – Acquisition and processing of available transformer shipments data.
2. Construction of aggregate shipments backcast – Provides an annual estimate of historical total capacity shipped using available shipments and electricity consumption data.
3. Construction of aggregate shipments forecast – Provides a future base case annual shipments estimate by applying a shipments growth rate.
4. Development of liquid-immersed and dry-type market shares – Disaggregates the total capacity shipped into liquid-immersed and dry-type transformers.
5. Modeling of purchase price elasticity – Models the impact of higher purchase prices due to a trial standard on future shipments.
6. Accounting of sales and in-service stocks – Provides an annual age distribution of in-service transformer stock from shipments estimates and the retirement function.
7. Consistency check with purchase and replacement data – Confirms that shipments model forecasts are consistent with available data on utility transformer purchases and replacements.

9.3 MODEL INPUTS

The shipments model inputs parallel the shipments calculation described in the previous section. The shipments model takes both external and internal inputs. Internal inputs comprise quantities that are calculated from previous steps in the model. The final outputs of the shipments calculation are the annual shipments estimates and the age distribution of in-service transformer stock. The list of specific inputs is as follows:

1. Shipments data – Includes external estimates of transformer shipments and quantity index of transformers manufactured.
2. Shipments backcast – Provides an estimate of total transformers capacity shipped before 2001.

3. Shipments forecast – Provides an estimate of total transformers shipped after 2001.
4. Long-term purchase elasticity – Estimates the price sensitivity of transformers shipped over the long term.
5. Dry-type/liquid-immersed market shares – Provides the annual capacity-based market shares of dry-type and liquid-immersed transformers shipped.
6. Stock accounting – Provides the age distribution of the current year's in-service transformer stock based upon the previous year's in-service stock and shipments.
7. Retirement function – Provides an estimate of the probability that a transformer will be replaced as a function of its age.
8. Initial stock – Provides the age distribution of the in-service stock of transformers at the start of the stock-accounting calculation (i.e., in 1950).

9.3.1 Shipments Data

The Department uses historical transformer shipments data to calibrate a forecast of future shipments and in-service stocks. These data are key inputs to the national impact analysis because changes in shipments and in-service stock create nearly proportional changes in the estimate of the energy savings from a trial standard.

The Department obtained an estimate of sales (for the entire market) for the year 2001, disaggregated by product class and kilovolt-ampere (kVA) rating.[1] The historical series of the power distribution and specialty transformer manufacturing (North American Industry Classification System (NAICS) code 335311) quantity index for 1977 to 2003 is available from the U.S. Bureau of Economic Affairs (BEA). The BEA transformer manufacturing quantity index provides information on changes to aggregate shipments from 1977 to 2003.[2] Market shares for both liquid-immersed and dry-type distribution transformers came from the 2001 shipments estimate by product type and kVA rating. Using the sales estimate for 2001 as a reference point and the BEA quantity index data, the Department estimated aggregate transformer shipments from 1977 to 2003.

Table 9.3.1 presents the shipment estimates in both units and megavolt-amperes (MVA) shipped and the approximate value of these shipments. The distribution transformer industry's total sales were about $1.6 billion dollars in 2001.

Table 9.3.1 Distribution Transformer Shipment Estimates for 2001

Product Class (PC)	Units Shipped	MVA Capacity Shipped	Shipment Value *2001$ million*
Liquid-Immersed, Medium-Voltage, Single-Phase, (PC 1)	977,388	36,633	698.8
Liquid-Immersed, Medium-Voltage, Three-Phase, (PC 2)	79,367	42,887	540.4
Dry-Type, Low-Voltage, Single-Phase, (PC 3)	23,324	983	17.8
Dry-Type, Low-Voltage, Three-Phase, (PC 4)	290,818	21,909	235.0
Dry-Type, Medium-Voltage, Single-Phase, 20-45 kV BIL,* (PC 5)	119	18	0.5
Dry-Type, Medium-Voltage, Three-Phase, 20-45 kV BIL, (PC 6)	650	776	13.5
Dry-Type, Medium-Voltage, Single-Phase, 46-95 kV BIL, (PC 7)	121	22	0.6
Dry-Type, Medium-Voltage, Three-Phase, 46-95 kV BIL, (PC 8)	2,371	3,913	68.1
Dry-Type, Medium-Voltage, Single-Phase, $\geq$96 kV BIL, (PC 9)	20	4	0.1
Dry-Type, Medium-Voltage, Three-Phase, $\geq$96 kV BIL, (PC 10)	187	367	6.4
Total	1,374,366	107,512	1,581.2

* BIL = Basic Impulse insulation Level

Tables 9.3.2 through 9.3.4 present the disaggregated shipment estimates for 2001 by product class and kVA rating.

Table 9.3.2 Liquid-Immersed Distribution Transformer Shipment Estimates, 2001

Liquid-Immersed, Medium-Voltage, Single-Phase		Liquid-Immersed, Medium-Voltage, Three-Phase	
kVA	**Units Shipped**	**kVA**	**Units Shipped**
10	114,594	15	-
15	167,234	30	-
25	277,581	45	605
37.5	66,977	75	1,816
50	242,931	112.5	4,842
75	44,214	150	9,078
100	49,696	225	9,078
167	9,762	300	17,552
250	2,158	500	17,552
333	1,188	750	6,219
500	1,040	1000	4,523
667	4	1500	3,769
833	8	2000	1,884
-	-	2500	2,450
Total Units	977,388	Total Units	79,367
Total MVA	36,633	Total MVA	42,887

Table 9.3.3 Dry-Type, Low-Voltage Distribution Transformer Shipment Estimates, 2001

Dry-Type, Low-Voltage, Single-Phase*		**Dry-Type, Low-Voltage, Three-Phase**	
kVA	**Units Shipped**	**kVA**	**Units Shipped**
15	2,554	15	24,484
25	4,573	30	56,511
37.5	4,396	45	65,474
50	9,759	75	85,354
75	1,108	112.5	24,150
100	929	150	17,265
167	-	225	9,505
250	4	300	5,460
333	-	500	2,190
-	-	750	420
-	-	1000	5
Total Units	23,324	Total Units	290,818
Total MVA	983	Total MVA	21,909

*Note: These estimates do not include sand-resin (epoxy-potted) units.

Table 9.3.4 Dry-Type, Medium-Voltage Distribution Transformer Shipment Estimates, 2001

Dry-Type, Medium-Voltage, Single-Phase				Dry-Type, Medium-Voltage, Three-Phase			
kVA	Units Shipped			kVA	Units Shipped		
	20-45kV BIL	46-95kV BIL	≥96kV BIL		20-45kV BIL	46-95kV BIL	≥96kV BIL
15	3	2	-	15	2	1	-
25	7	3	-	30	4	2	-
37.5	10	5	-	45	4	2	-
50	17	8	-	75	7	3	-
75	20	25	5	112.5	20	11	-
100	20	25	5	150	18	11	-
167	12	15	3	225	20	19	1
250	6	8	1	300	59	60	2
333	12	15	3	500	76	150	5
500	12	15	3	750	80	177	5
667	-	-	-	1000	80	320	10
833	-	-	-	1500	80	390	32
-	-	-	-	2000	100	575	56
-	-	-	-	2500	100	650	76
Total Units	119	121	20	Total Units	650	2,371	187
Total MVA	18.4	22.1	4.1	Total MVA	776	3,913	367

There are two major assumptions inherent in the shipments model. The first major assumption is that the relative market shares of the different transformer product classes and size categories are constant over time. In actuality, there is probably a gradual increase in the average size of transformers as the electricity demand per customer increases, but the Department does not have sufficient data to characterize such transformer size trends.

The second major assumption concerns the use of the BEA quantity index data. The BEA index data actually include shipments of transformers other than those covered by this rulemaking. The use of the BEA Standard Industrial Classification (SIC) code 3612 (NAICS code 335311) quantity index to estimate shipments for products under this rulemaking assumes that the quantity market share of distribution transformers relative to all NAICS code 335311 transformers is relatively constant over the period from 1977 to 2003. The Department made this assumption because more disaggregated quantity index data were not available.

9.3.2 Shipments Backcast

The shipments backcast is the estimate of previous aggregate transformer shipments based on limited historical data. The backcast of transformers shipments is a key element in estimating age distributions of future in-service transformer stock.

The shipments backcast begins with the estimate of transformer shipments in the year 2001[1] and uses BEA's NAICS code 335311 quantity index to estimate total shipments in the period 1977 to 2003.[2] Specifically, the Department used the following equation to backcast shipments from 2003 to 1977:

$$TotShip(y) = TotShip(2001) \times BEA(y) / BEA(2001) \qquad \textbf{Eq. 9.1}$$

where:

TotShip(y)	=	the total capacity of transformer shipments estimated for year *y* where 1977 $\leq y <$ 2003 (MVA),
TotShip(2001)	=	the total transformer capacity shipped, from the shipment estimate, (MVA), and
BEA(y)	=	the BEA quantity index for year *y*.

Annual shipments of transformer capacity for years prior to 1977 are backcast to 1950 using annual growth of electricity consumption from Table 8.9 of DOE's Energy Information Administration (EIA) *Annual Energy Review 2003*, a proxy for growth of transformer sales during this period.[3] Using this method, the shipments for the years 1950 to 1977 are given by the following equation:

$$TotShip(y) = TotShip(1977) \times AllElec(y) / AllElec(1977) \qquad \textbf{Eq. 9.2}$$

where:

TotShip(y)	=	the total capacity of shipments estimated for year *y* where 1950 $\leq y$ < 1977 (MVA), and
AllElec(y)	=	national electricity consumption in year *y* according to EIA's *Annual Energy Outlook 2005 (AEO2005)* (W-hr).[4]

9.3.3 Shipments Forecast

After constructing a shipments backcast and calibrating it with shipments data, the Department constructed a forecast of transformers shipments. This forecast provides the necessary input for equipment expense and in-service transformer stock accounting.

The Department constructed a simplified forecast of transformer shipments for the base case scenario based on the assumption that long-term growth in electricity consumption will drive transformer shipments. The detailed dynamics of transformer shipments is highly complex. This complexity can be seen in the fluctuations in the total quantity of transformers manufactured as expressed by the BEA transformer quantity index. The Department examined the possibility of modeling the fluctuations in transformers shipped using a bottom-up model where the shipments are triggered by retirements and new capacity additions, but found insufficient data to calibrate model parameters within an acceptable margin of error. Hence, the Department de-coupled the overall shipments and retirements in the construction of the shipments forecast and maintained the age distribution of the in-service transformer stock using a retirement function. Figure 9.3.1 shows the estimated age distribution of the in-service stock of liquid-immersed transformers in 2004. The Department developed similar age distributions for low-voltage and medium-voltage dry-type transformers.

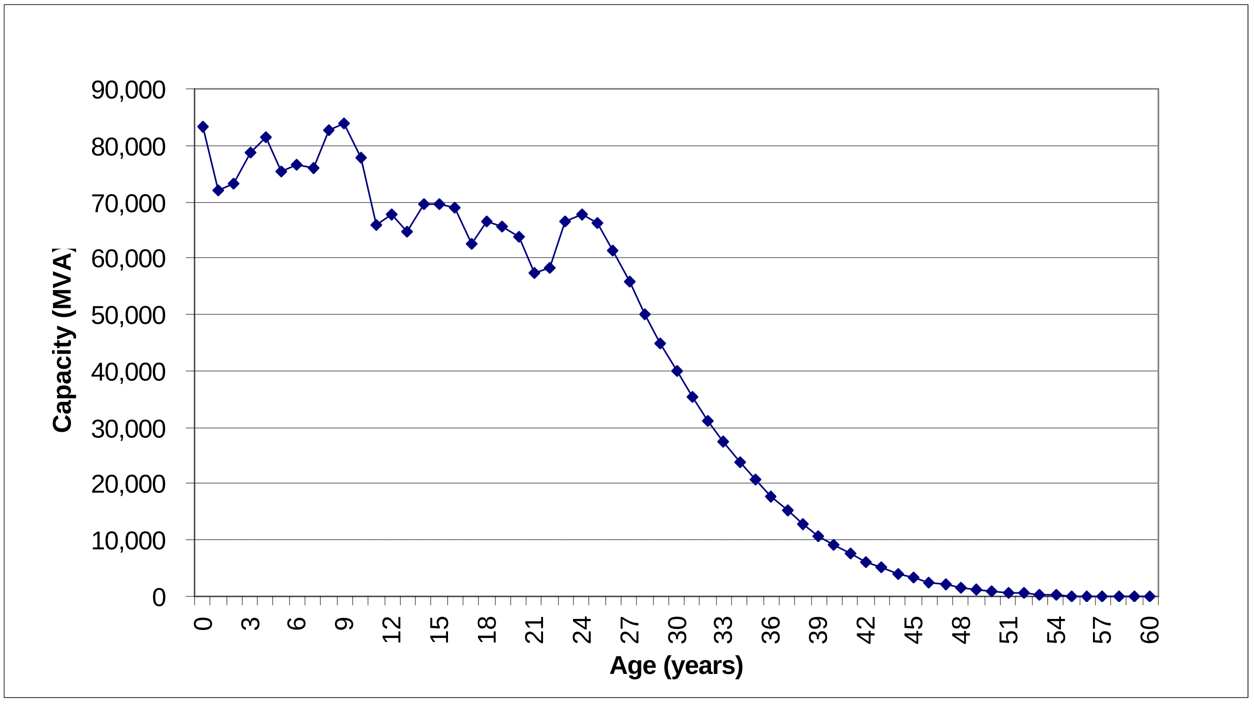

Figure 9.3.1 Age Distribution of Liquid-Immersed In-Service Transformer Stock in 2004

The Department constructed the transformer shipments forecast assuming that transformer shipments growth is equal to forecasted growth in electricity consumption as given by the *AEO2005* forecast up to the year 2025.[4] For the years from 2026 to 2038, DOE extrapolated the *AEO 2005* forecast using its growth rate of electricity consumption between 2015 and 2025. Specifically, the Department used the following equation for the shipments forecast:

$$TotShip(y) = TotShip(2001) \times AllElec(y) / AllElec(2001) \qquad \textbf{Eq. 9.3}$$

where:

TotShip(y) = the total capacity of shipments estimated for year *y* where $2003 < y \leq 2038$ (MVA), and

AllElec(y) = national electricity consumption forecasted for year *y* by *AEO2005* (or by an extrapolation of *AEO2005* data) (W-hr).

The next section describes how the Department adjusted its base case scenario forecast to account for price increases arising from a trial standard.

9.3.4 Long-Term Purchase Elasticity

The Department used a purchase elasticity to adjust the base case shipments forecasts for potential transformer price increases due to a trial standard. The long-term purchase elasticity is a measure of how sensitive transformer shipments are to potential increases in price. Elasticity is defined as the percentage change in quantity purchased divided by the percentage change in price (or some other factor that influences purchase behavior).

The basic formula used to determine price elasticity is:

$$e = (dQ/Q) / (dP/P) \qquad \textbf{Eq. 9.4}$$

where:

dQ/Q = a small percentage change in quantity purchased (*Q*), and

dP/P = a small percentage change in price.

If the elasticity is constant, then the quantity purchased can be written in terms of the price, a reference price, a reference quantity, and the elasticity. Specifically, the following equation holds true when the elasticity is constant:

$$Q(P) = Q_0 \times (P/P_0)^{e} \qquad \textbf{Eq. 9.5}$$

where:

$Q(P)$	=	the quantity purchased as a function of price,
Q_0	=	a reference quantity at a reference price P_0, and
e	=	the elasticity, which is almost always negative or zero (i.e., non-positive) with respect to price.

For the forecast, the reference price and the reference quantity are the price and quantity from the base case scenario. A change in price due to a trial standard then has an impact on the quantity purchased, $Q(P)$, as described by the above equation.

9.3.4.1 Elasticity Estimates for Liquid-Immersed and Dry-Type Transformers

The Department constructed a model employing a standard econometric logit equation, used for general applications of market response to costs and perceived utility, to model utility and customer decision-making. For liquid-immersed transformers, the model was fitted to transformer purchase data from FERC Form No. 1[5] to determine the parameters of the logit equation. This resulted in a value of -0.04 for price elasticity. The Department assigned -0.04 as the *medium* scenario and incremented the elasticity to -0.2 to implement a *high* sensitivity to price change. The *low* scenario assumes zero elasticity, or no impact on purchase decisions from a price change.

For dry-type transformers, historical purchase data was not available. Since dry-type units are primarily used in commercial and industrial applications, as are unitary air conditioners, the Department used sales and price data for the latter for estimating price elasticity. The model was fitted to the Air-Conditioning and Refrigeration Institute's sales data[6] and real Producer Price Index (PPI) of unitary air conditioners.[7] The resulting value of elasticity was -0.02. The Department assigned -0.02 as the medium scenario and incremented the elasticity to -0.2 to implement a high sensitivity to price change. The low scenario assumes zero elasticity, or no impact on purchase decisions from a price change.

9.3.5 Liquid-Immersed/Dry-Type Market Shares

The shipments forecast and backcast described above provide an aggregate estimate of the total capacity of transformers shipped from 1950 to 2038. In order to disaggregate the total capacity into the capacity for different types of transformers, the Department applied a capacity market share estimate. To distinguish between liquid-immersed and dry-type transformers, the Department applied a liquid-immersed and dry-type market share, respectively. To distinguish between different product classes and size categories within each product class, the Department used 2001 market shares estimates.

The Department used trends in electricity consumption from EIA's retail sales data to estimate market share trends for liquid-immersed and dry-type transformers.[3] Assuming that transformer sales over the long term track electricity sales for the sectors served by those transformers, the following market share model can be derived:

$$LiqShip(y) = CL \times AllElec(2001); \quad where\ CL = LiqShip(2001) / AllElec(2001) \qquad \textbf{Eq. 9.6}$$

$$DryShip(y) = CD \times CIElec(2001); \quad where\ CD = DryShip(2001) / CIElec(2001) \qquad \textbf{Eq. 9.7}$$

$$DryMS(y) = CD \times CIElec(y) / (CL \times AllElec(y) + CD \times CIElec(y)) \qquad \textbf{Eq. 9.8}$$

$$LiqMS(y) = 1 - DryMS(y) \qquad \textbf{Eq. 9.9}$$

where:

CL	=	the constant of proportionality between the electricity consumption and the sales of liquid-immersed transformers in the year 2001,
CD	=	the constant of proportionality between the electricity consumption and the sales of dry-type transformers in the year 2001,
LiqShip(2001)	=	the capacity of liquid-immersed transformers shipped in 2001 (MVA),
DryShip(2001)	=	the capacity of dry-type transformers shipped in 2001 (MVA),
AllElec(y)	=	the total consumption of electricity in year *y* (W-hr),
CIElec(y)	=	the consumption of electricity by the commercial and industrial sectors in year *y* (W-hr),
LiqMS(y)	=	the capacity market share of liquid-immersed transformers in year *y* (%), and
DryMS(y)	=	the capacity market share of dry-type transformers in year *y* (%).

The key assumption behind the market share equations is that transformer capacity market shares follow the relative electricity consumption of the end users of the electricity that passes through the transformers. The dynamics of liquid-immersed and dry-type market shares are likely to be fairly complicated, but the Department believes this is the best way to capture long-term average trends in market share given the lack of detailed market share data over long time periods.

For the market shares of different kVA ratings and product classes, the Department assumed that the relative market share within each transformer type (i.e., liquid-immersed or dry-type) is constant over time. Given a lack of detailed, long-term, market share data, an alternative assumption regarding kVA ratings and product class market shares may not be feasible.

Once the shipments backcast, forecast, elasticity, and market shares are fully specified, the characteristics of transformer shipments are completely specified. The next step is to provide an accounting of in-service transformer stocks, as described in the next section.

9.3.6 Stock Accounting

The stock accounting takes transformer shipments, a retirement function, and initial in-service transformer stock as inputs and provides an estimate of the age distribution of in-service transformers stocks for all years. The age distribution of in-service transformer stocks is a key input to both the NES and NPV calculations, since the operating costs for any year depend on the age distribution. The dependence of operating cost on the transformer age distribution occurs because under a trial standard scenario that produces increasing efficiency over time, older, less-efficient transformers may have higher operating costs, while younger, more-efficient transformers will have lower operating costs.

The Department calculated total in-service stock of distribution transformers by integrating historical shipments starting from the year 1950. As transformers are added to the in-service stock, some of the older ones retire and exit the stock.

To estimate the shipment forecasts, the Department developed a series of equations that define the dynamics and accounting of in-service transformer stocks. For new units, the equation is:

$$Stock(y, age = 1) = Ship(y - 1) \qquad \textbf{Eq. 9.10}$$

where:

Stock (y, age)	=	the population of in-service transformers of a particular age (MVA),
y	=	the year for which the in-service stock is being estimated, and
Ship (y)	=	the number of transformer purchased in a particular year (MVA).

This equation says that the number of one-year-old units is simply equal to the number of new transformer units purchased the previous year. The slightly more complicated accounting equations are those which describe the accounting of the existing in-service stock of transformer units:

$$Stock(y+1, age+1) = Stock(y, age) \times \left[1 - Prob_{Retire}(age)\right] \qquad \textbf{Eq. 9.11}$$

This equation says that as time goes on, only a fraction of the in-service stock exists in the next year. As the year is incremented and goes from *y* to *y+1*, the age is also incremented from *age* to *age+1*. Also as time moves forward, a fraction of the in-service stock is removed, and that fraction is determined by a retirement probability function, $Prob_{Retire}(age)$, which is described in the next section.

9.3.7 Retirement Function

The accounting of in-service transformer stock requires specification of a retirement probability function. The Department derived the retirement probability function from a modified version of a transformer reliability function. The reliability function for determining the lifetime of the transformer is adapted from an earlier study for the Department, *ORNL 6804/R1*, p. D-1.[8]

$$r(age) = \exp\left[-\left(\frac{age}{d}\right)^{e}\right]\left(\left(1-constfail\right)^{age}\cdot\left(1-corrfail\right)^{age-15}\right) \qquad \textbf{Eq. 9.12}$$

where:

r(age)	=	the reliability of a transformer of a certain age, where reliability is defined as the probability that a transformer will last to a particular age,
d and *e*	=	parameters used for fitting the reliability data,
constfail	=	a constant failure rate of 0.5% per year[a], and
corrfail	=	a corrosive failure rate of 0.5% per year at age 15 and above.

The parameters of the *Weibull*[b] distribution are adjusted to maintain an average lifetime of 32 years. The failure rates and the lifetime are adapted from *ORNL 6804/R1*, p. D-1.

The Department converted the reliability function into an annual retirement probability function by dividing the incremental reliability at a given age by the fraction of transformers that last to that age as shown below:

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[a] Constant failure could be due to lightning or other random events.

[b] The *Weibull* distribution is one of the most widely used lifetime distributions in reliability engineering. It is used to model material strength, times-to-failure of electronic and mechanical components, equipment or systems.

$$Prob_{Retire}(age) = [r(age-1) - r(age)] \,/\, r(age) \qquad \textbf{Eq. 9.13}$$

where:

$Prob_{Retire}(age)$ = the probability that a transformer of a particular age will be retired.

Figures 9.3.2 shows the retirement rate of distribution transformers.

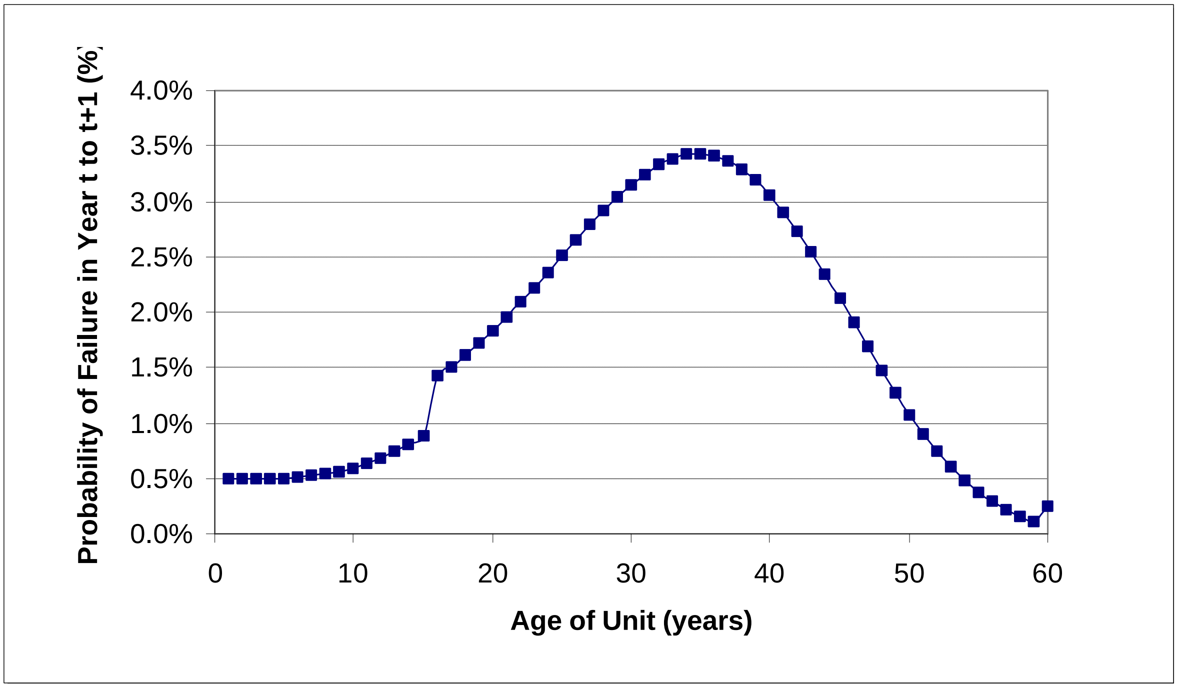

Figure 9.3.2 Fraction of Original Shipment Retiring

Once the retirement probability function is specified, the remaining input to the stock-accounting equation is the initial in-service stock of transformers as described in the next section.

9.3.8 Refurbishments and Rewinds

Transformers that are not retired can be refurbished and returned to the stock. Minor refurbishments may include replacement of connectors, bushings, or the oil. Major refurbishments could include the rewinding of the transformer, a function often performed by a rewinding firm. *ORNL-6804/R1* reported annual refurbished capacity, including rewound units, to be approximately 1% of the in-service transformer capacity. The Department carried out further research and had discussions with owners of transformers to ascertain the estimated annual refurbishments. The findings were inconclusive: major refurbishment appears to represent a small fraction of the distribution transformer market (however, that share could potentially grow with the imposition of an energy-efficiency standard). Transformer users expressed hesitancy regarding widespread adoption of rewound transformers. Not finding a consensus regarding transformer refurbishment, the Department did not include major refurbishments in the current analysis. Minor refurbishment is widespread and is already captured in the retirement function.

9.3.9 Initial Stock

The Department initialized the stock-accounting model in the year 1950 which was the first year that electricity consumption data was available.[3] For simplicity, the Department set the in-service transformer stock in the first year at zero.[a] This number does not affect the analysis because most of the transformer stock from the year 1950 will no longer be in service post-2001.

9.3.10 Effective Date of Standard

A key output of the shipments model is the in-service stock of transformers that may be affected by a standard. To calculate this ‘affected stock,’ the effective date of the trial standard must be defined. The Department assumed for this analysis that any new energy-efficiency standard for distribution transformers will become effective in 2010. The exact effective date of the standard is January 1, 2010, so that all distribution transformers purchased starting on the first day of the year 2010 are affected by the standard.

9.3.11 Affected Stock

The affected stock is an output of the shipments model and a key input for the NES and NPV calculations. The affected stock consists of that portion of the in-service transformer stock that is potentially impacted by a trial standard level. It therefore consists of those in-service

[a] Note that transformer stocks in 1950 were quite small compared to transformer stocks in 2001.

transformers that are purchased in or after the year the trial standard level has taken effect, as described by the following equation:

$$Aff\_Stock(y) = Ship(y) + \sum_{age=1}^{y-Std\_year} Stock(age) \qquad \textbf{Eq. 9.14}$$

where:

Aff_Stock(y)	=	stock of transformers of all vintages that are operational in year *y* (MVA);
Ship (y)	=	shipments in year *y* (MVA), and
age	=	the age of the transformer (years).

Once the shipments, in-service stocks, and affected stocks of transformers have been completely specified, it is possible to proceed to the NES and NPV models and calculations, as described in the Chapter 10.

9.4 RESULTS

The main output of the shipments model is the total capacity of distribution transformers shipped annually from 2010 through 2038. Total shipments depend on transformer lifetime and growth in new electricity demand. The Department does not expect any direct effect on total shipments in the long term from energy-efficiency standards. Total shipments for all trial standard levels (TSLs) for liquid-immersed and dry-type distribution transformers are shown in Table 9.4.1.

Table 9.4.1 Cumulative Shipments of Transformers by Trial Standard Level, 2010–2038

Distribution Transformers	Transformer Capacity Shipments in Thousand MVA						
	Base Case	**TSL 1 (TP 1)**	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**	**TSL 6**
Liquid-Immersed	3501.3	3498.7	3494.7	3487.2	3484.4	3452.1	3420.7
Dry-Type	1290.6	1289.4	1288.2	1286.6	1283.7	1277.7	1277.6

An important factor that influences the size of the potential standards-induced change is the actual equipment price increase due to standards. If price increases are large, the shipments volume will decrease almost proportionally to the price increase, but because the price elasticity of transformers is less than one, price increases will result in increased gross sales dollar volume to the transformer manufacturer. The net financial impact of these opposing effects is examined in the manufacturer impact analysis in Chapter 12.

The national impact spreadsheet is available as a Excel file on the DOE website: http://www.eere.energy.gov/buildings/appliance_standards/commercial/distribution_transformers.html. Instructions for using the spreadsheet are in Appendix 10A of this TSD.

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